KIMMERIDGE
Energy

Why Kimmeridge

March 2014

Why Kimmeridge?

What is in a name? In the case of Kimmeridge Energy, quite a lot. Kimmeridge comes from the name of a significant Upper Jurassic aged source rock that generated most of the oil and gas in the North Sea (>50Bn bbl produced and discovered), which itself is named after the village of Kimmeridge (and Kimmeridge Bay), in Dorset on the south coast of England where the formation outcrops (Figure 1). It was in this area that the rock was first used unconventionally as an energy source in the 16th century, and later mined extensively.

Due to its very high organic properties and associated dolomite layers, it could also be a very good candidate for the first offshore unconventional play in the future, as only limited amounts of the formation are in the oil window onshore in England. So on top of the historical unconventional hydrocarbon exploitation of the Kimmeridge Clay hundreds of years ago, there may be a long future ahead for this formation.

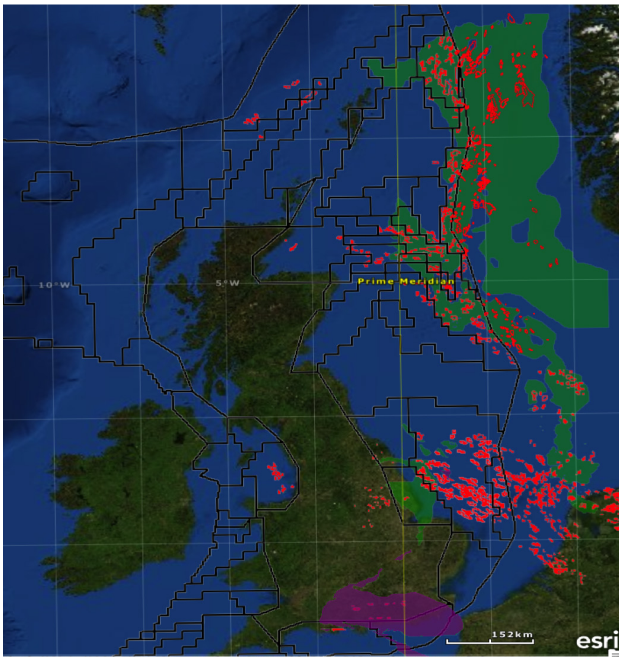

Figure 1: Distribution of the Kimmeridge Clay On and Offshore Europe in Green and Purple; Oil and Gas feilds in Red

A Little History - the Kimmeridge Clay, One of the First Unconventional Plays

Oil and gas have been associated with the Kimmeridge Clay for a very long time, but came into prominence in the late 1960's, 70's with the oil discoveries in the North Sea.

The Romans are known to have mined the Kimmeridge Blackstone, as it was known, to produce polished, black armlets or bangles. Then in the 17th century Sir William Clavell, owner of the land around Kimmeridge, used the Kimmeridge oil shale as fuel for glass-making, and for boiling sea-water to manufacture salt. By the mid 19th century, oil was produced extensively from the Kimmeridge oil shale, by heating the shale, but so too was gas. One ton yielded 11,300 ft. of 20 candle gas compared to 15,480 ft of 52 candle gas from Boghead Coal, or torbanite (algal oil shale) from West Lothian, Scotland.

In 1848 the Bituminous Shale Company in Dorset built a tramway and worked the oil shale, utilising a small port to export the unretorted shale. The oil shale was converted into varnish, grease, pitch, naptha, dyes, wax, fertiliser and other by-products at nearby Weymouth. In the same year, Wanostrocht and Company used Kimmeridge oil shale to light the streets of Wareham with 130 gas lamps, and later had a contract to light the streets of Paris using gas from burning imported Kimmeridge Clay. By 1890, the Kimmeridge Oil and Carbon Company reported that there were 5000ft of underground tunnels or levels at Kimmeridge, but in the Late 1890s, oil shale mining came to an end.

The Kimmeridge Clay's main competition back in the mid 19th century, was from the Lower Carboniferous oil shales of the Scottish Lothians, west of Edinburgh, which were continuously worked from 1851 to 1962, and at their maximum productivity before the First World War, had an annual output of over 3 million tons of shale oil. The initial purpose of the industry was to produce lubricating oils and paraffin for heating and lighting, which was profitable at the time. But as the conventional crude oil exploration and production industry took off, the more expensive unconventional techniques of retorting (heating up the rock to extract oil and gas), found it increasingly hard to compete with their conventional relatives.

Ironically, today there is also a conventional oil well on the cliff above Kimmeridge Bay, but this is actually not related to the Kimmeridge Clay itself. The well is the oldest continuously producing well site in the UK and was drilled in 1959, and has produced around 350 barrels per day from fissured shelly limestone of the Middle Jurassic Cornbrash at about 320m (1050ft) depth. Indeed, the source of the oil is actually the Lower Jurassic Lias shale (equivalent to the main oil source rock in both the Lower Saxony Basin in Germany and the Paris Basin in France), because the Kimmeridge Clay at Kimmeridge is not thermally mature. The formation has also been in the news recently, as it is the focus of recently renewed exploration in the Weald Basin, onshore England, to the south of London.

Is it a World Class Source Rock With Unconventional Potential?

The Kimmeridge Clay was formed at the same time, and in similar conditions to the Haynesville Shale in the southern USA, and has comparable properties to many significant N. American unconventional plays (Figure 2 & 3). The Kimmeridge Clay is a Type II source rock, with TOC (total organic carbon) ranging from 2% to more than 15%, with the "Blackstone or Kimmeridge Coal" unit at outcrop in Kimmeridge Bay having up to 70% TOC.

	Bakken	Eagle Ford	Toarcian	Posidonia	Kimmeridge
Basin	Williston Basin	Maverick Basin	Paris Basin	Lower Saxony Basin	North Sea
Basin type	Intracratonic	Rift	Intracratonic	Graben	Graben
Age	Devonian-Mississippian	Upper Cretaceous	Lower Jurassic	Lower Jurassic	Upper Jurassic
Primary target interval	Middle Bakken	carbonaceous shale	Banc de Roc	limestone interbeds	limestone interbeds
Area of mature source rock (M acres)	17.0	11.7	1.6	1.8	26.4
Source rock thickness (ft)	10-75	50-600	30-500+	50-260	200-650
Kerogen type	II	II	II	IIS	II
Average original TOC (wt.%)	16	5	5	10	6
Original Hydrogen index (mg/g TOC)	625	650	600	650	600
Maturity (Vr% or Equivalent)	0.75	0.74	0.85	0.95	0.80
Typical S1 (mg HC/g rock) in Oil Window	12.0	4.8	5.0	6.0	5.0
Average Petroleum yield (S1+S2)	162	32	65	66	68
Est. basin generative potential (Bnboe)	>400	>800	>95	>100	>2,000
Cum. conventional oil production (Mboe)	205	>775	>300	>850	>50 Bnboe
Drill depth (ft)	8850-11000	4000-10000	5900-8850	5900-9850	6500-13,000
Quartz content (%)	20-68%	2-40%	26-58%	20-55%	27-37%
Carbonate content (%)	High in Middle Bakken	10-90%	High in Banc de Roc	35-61%	up to 80%
Porosity (%)	2-10%	4-15%	up to 12%	6%	up to 15%
Permeability (mD)	5,000-10,000 nD	400-1000 nD	up to 5 mD	up to 6 mD	up to 1mD
Pressure	Overpressured	Overpressured	Overpressured	Overpressured	Overpressured
Old wells with historic production	Yes	Yes	Yes	Yes	Yes
Oil API gravity (deg)	38-40	42	38	37.7	38
Oil sulfur content (%)	0.2-0.5	Low	0-0.5	0.3	0.40%

Figure 2: Comparison of Source Rock characteristics between the Kimmeridge Clay and other known unconventional plays

KIMMERIDGE Energy

One potential drawback that has been associated with the Kimmeridge Clay as an unconventional reservoir is its clay content (which can decrease the effectiveness of fracking), from whence its name derives. However, the average expandable clay content (which is the primary driver of ductility) appears to be between 25-30% which is very manageable, and compares favorably with the Barnett shale at around 40% clay. Moreover there are also many sections and examples with high carbonate and siliclastic (silt and sand) content, which would aid produce-ability. Additionally, from a resource richness perspective, the Oil-in-Place or Gas-in- Place of shales is positively related to TOC and clay content, both of which aid adsorption of hydrocarbons.

Although the Kimmeridge Clay at Kimmeridge is not mature with an Ro (standard industry measure of thermal maturity) of about 0.45 (just below the early oil maturity stage), the lower parts of the Kimmeridge Clay Formation in the nearby Arreton No. 2 Borehole on the Isle of Wight, are marginally mature with an estimated Ro: 0.50 to 0.60%. However, in the North Sea, the deepest core samples indicate that the Kimmeridge Clay is thermally mature with vitrinite reflectance (Ro) values of ~1.2% in the early gas window.

In this offshore, thermally mature setting, other units within the formation might be suitable reservoir targets for unconventional exploration. As mentioned previously, the formation also contains a number of dolomite layers, such as the Flats Dolomite Bed, Maple Ledge dolomite and the Washing Ledge dolomite, which all have kerogen streaks in them at Kimmeridge Bay. It is assumed that these dolomite beds could become saturated with oil as the Kimmeridge Clay enters the oil window in certain conditions, and in the North Sea many sandstone conventional reservoir rocks are interbedded with it and have been targeted by offshore exploration.

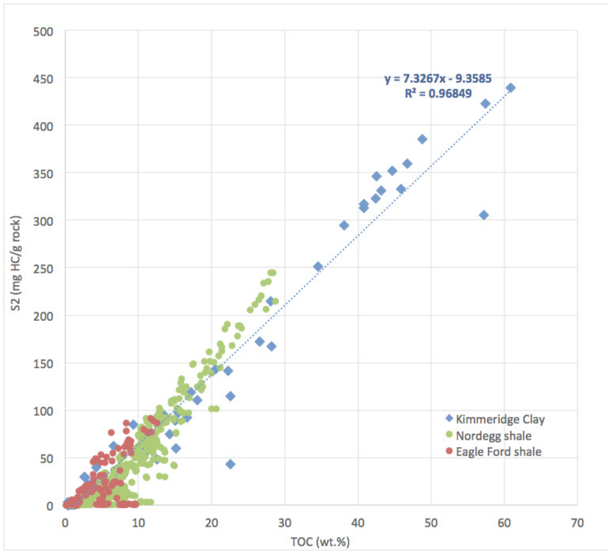

Figure 3: Comparison of the organic content and oil generative potential of the Kimmeridge Clay (Blue) versus similar shales such as the Nordegg (green) andd Eagleford (Red)

The Kimmeridge Clay in the North Sea

The Kimmeridge Clay underlies most of the northern North Sea and is considered the major source rock for North Sea oil. By our estimates the Kimmeridge Clay in the North Sea, generated over 2000Bnboe of hydrocarbons in the UK and Norwegian sectors, with some 50BnBoe of oil and gas having been discovered and/or produced.

Interestingly, the USGS (US Geological Survey), estimates that the North Sea Graben contains between 4.3 and 25.6 billion barrels (BBO) of undiscovered, conventionally recoverable oil, and between 11.8 and 75 trillion cubic feet (TCF) of undiscovered natural gas. Most of these potential volumes lie in areas of the North Sea where the Kimmeridge Clay is mature today for oil and/or gas. However, the cost of finding and developing these conventional fields has increased significantly, as the individual field sizes have decreased and as historic infrastructure prepares to be abandoned, following declines in the volumes from fields discovered in the '70s, '80s and '90s.

What does not seem to have been considered by the USGS, is the potential in the Kimmeridge Clay source rock itself. As we have discussed in previous research, up to 50% of the oil and gas generated in a source rock can stay within the source rock or very close to it. In the case of the Kimmeridge Clay in the North Sea, this would mean that around 1000BnBoe of hydrocarbons remain in and around the source rock today, so even at a recovery rate of a few percent the volumes are still significant. However, the problem in the North Sea is how to explore for, and exploit this potential. Obviously, if the "North Sea" petroleum province had been on present day land, it would be one of the major centers of unconventional exploration, development and production outside N.America. So unless we wait for another ice age when large parts of the North Sea were indeed land, we suspect that the only solution to explore for the Kimmeridge Clay potential today, is to re-enter wells from fields which are at the end of their conventional life and target the Kimmeridge Clay through large horizontal wells and hydraulic fracturing.

The main source rocks in the North Sea include the Kimmeridge Clay in the Moray Firth/ Witch Ground Graben, and its equivalents, the Mandal Formation in the Central Graben, the Draupne Formation in the Viking Graben, and the Tau Formation in the Norwegian-Danish Basin (Figure 4). Kerogen in these shales is a typical "type II" marine source rock with some influence from land derived material. The average TOC is 5% (which is depleted from its original values due to maturity) with a hydrogen index of 450–600 depending on maturity and richness. The Kimmeridge Clay Formation is widely distributed in the North Sea, and where it has the highest maturity it can have a thickness of over 1100m in the South Viking Graben, and about 300m in the Central North Sea (although net organic-rich source rock thickness is believed to range from 70-200m). Within the Kimmeridge Clay there are also a number of discrete sand bodies which have become conventional oil traps with many discoveries, and a major source of production in the basin.

The Kimmeridge Clay in the North Sea actually lies close to two sets of conventional reservoir models. As oil will migrate using the easiest avenues to porous and permeable conventional reservoir rocks, it is no surprise in the North Sea that there are numerous conventional reservoirs, both within and surrounding the Kimmeridge Clay in Upper Jurassic sandstones as well as in the Middle Jurassic just below it (Figure 5). Conventional fields with these characteristics, in locations where the Kimmeridge Clay has the highest generative potential (due to source rock richness and thickness), and is at the right present day maturity, could be targets for the first offshore unconventional exploration over the next decade. In particular, from our analysis there are two groups of conventional oil fields that have high potential if wells which have already been drilled can be reused, as these fields come to the end of their lives.

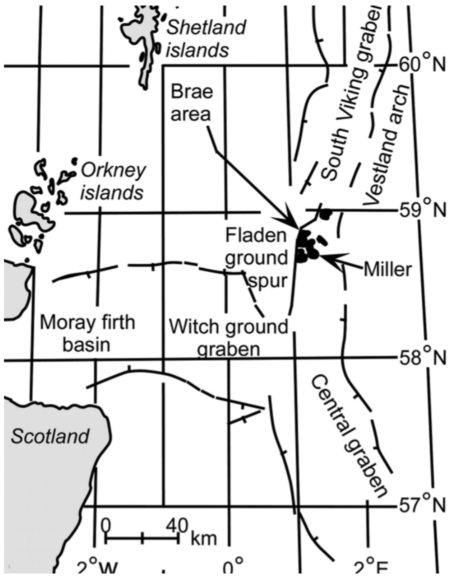

Figure 4: Location map of the basins within the North Sea

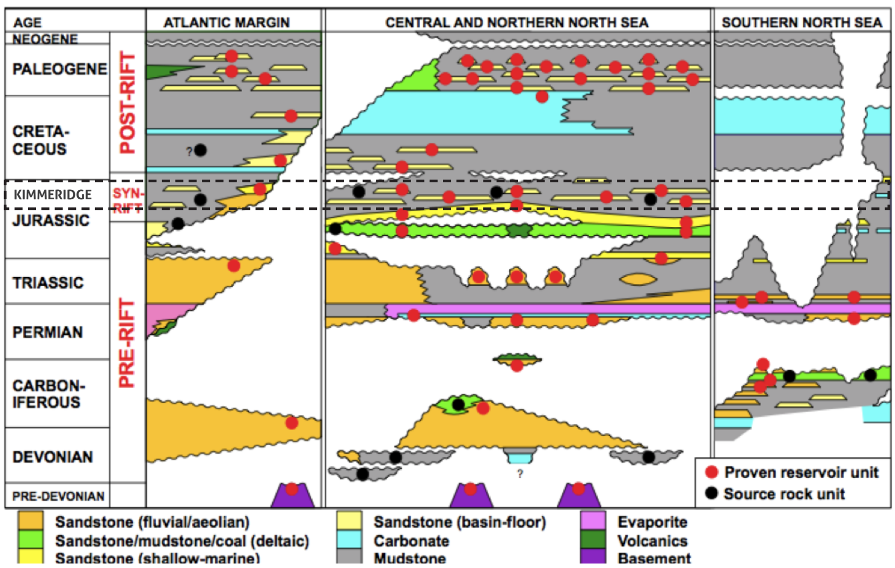

Figure 5: Stratigraphic diagram showing the relationship of the Kimmeridge Clay source rock (highlighted) to adjacent oil reservoirs

For example, in the South Brae Field (Figure 6a) the reservoir contains oil and gas and was deposited as sandy debris which accumulated at the foot of a steep submarine slope offshore a land mass in the Late Jurassic period. At this time, 140 million years ago, the organic mud of the Kimmeridge Clay source rock was being deposited across the area. These reservoir rocks are now found as sand wedges interlayered with the oily source rock. Here, therefore, the reservoir rock is the same age as the source rock.

Another style of conventional oil field in the North Sea that may be an unconventional target is the Brent Field (Figure 6b), discovered in the far northern part of the North Sea in 1971, with oil and gas within tilted layers of sandy rock. The Kimmeridge Clay, drapping across the titled blocks, and when the source rock matured following burial, the oil was expelled downwards into the sandstones.

Figure 6a: South Brae Feild

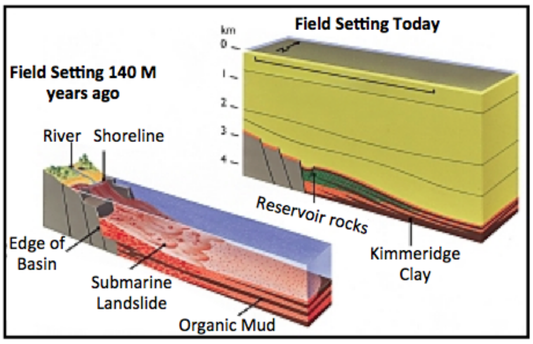

Figure 6b: Brent Feild

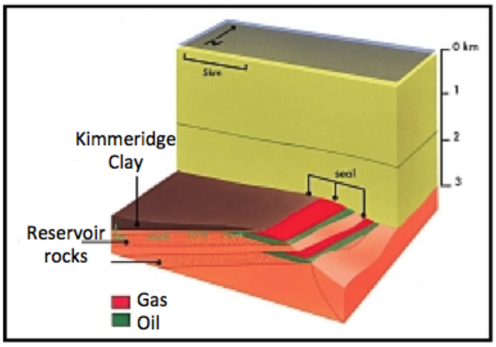

Figure 6: Relationship of the Kimmeridge Clay source rock to the interbedded reservoir of the South Brae field, and to the underlying reservoirs in the Brent field

Maturity of the Kimmeridge Clay relates to its present day burial (Figure 7 & 8). Based on the level of thermal maturation of the source rocks, it is calculated that hydrocarbon generation from the Kimmeridge Clay occurred from the Late Cretaceous to the Early Paleocene along the deeper parts of the Viking and Central Grabens. Peak oil maturity occurs today between 2500m and 3,250 m (0.7 percent R0) and was first reached 40 to 50 Ma ago. However, the current maturity of the Kimmeridge Clay in the center of the North Sea, which is essentially a three pronged basin, ranges from early mature in the Witch Ground Graben to the west, and into the gas window in the Central Graben and to the north in the south Viking Graben (Figure 9).

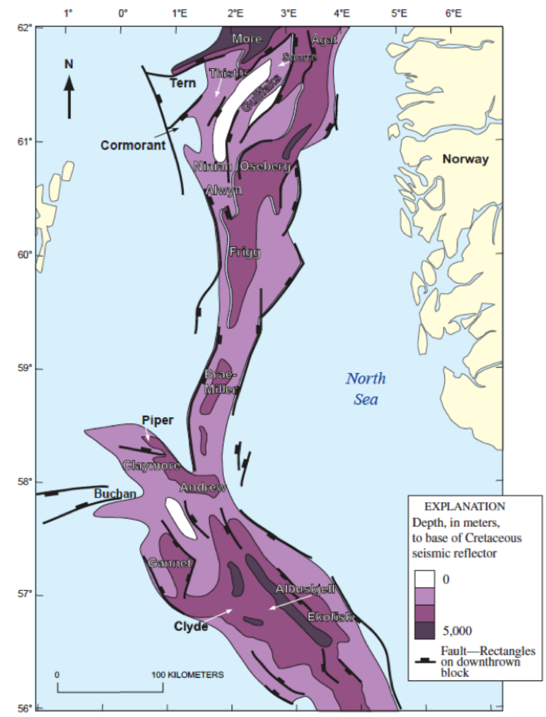

Figure 7: Depth of Base Cretaceous, just above the Kimmeridge Clay, which corresponds to maturity

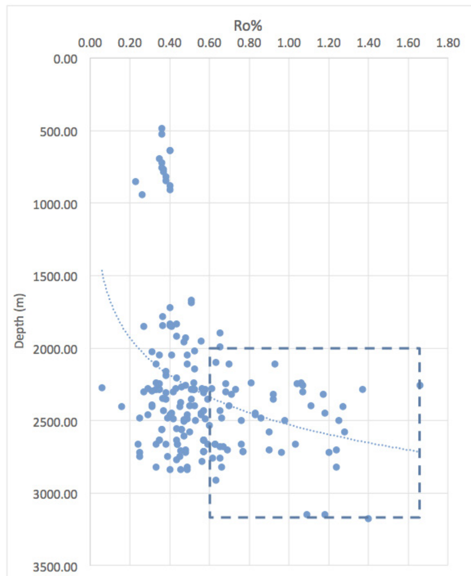

Figure 8: Maturity Data versus depth from Dutch Central Graben and Wessex Basin UK

Throughout the Tertiary period, maturation increased as the basin continued to subside. With the maturity moving through the oil generation stage into wet-gas and/or condensate generation and finally into the dry-gas stage, the areas of strong active oil generation migrated both laterally and vertically into surrounding reservoirs.

The highest oil saturations in the Kimmeridge Clay occur at a maturity of 0.8% Ro, and here oil expulsion efficiencies are >50-80 percent. The Viking and Central Graben areas, as well as Norwegian-Danish basin, saw the highest amounts of hydrocarbons generated from the Kimmeridge Clay (due to a combination of the source rock quality, thickness and maturity) (Figure 10). In these areas where conventional structural traps occurred just above the Kimmeridge Clay, significant vertical migration up faults sourced many major oil fields.

Academic research on the expulsion and migration efficiency (hydrocarbons in place in conventional fields/hydrocarbons generated from the Kimmeridge Clay) is in line with our estimate of 5-10% from previous research pieces (see our previous research piece "Brother From the Same Mother? The Relationships Between Unconventional and Conventional Oil and Gas Resources" from September 2012). However, individual conventional hydrocarbon accumulations adjacent to the mature Kimmeridge Clay, or directly above it and connected by faults have values as high as 40%, indicating a virtually saturated hydrocarbon system.

Key fields whose reservoirs inter-fingered with the Kimmeridge Clay, or were adjacent to it, are mainly located in the South Viking Graben (e.g. Miller and Brae), as well as in North Viking Graben, (e.g. Magnus field). However, the "core" of the Kimmeridge offshore play is massive (Figure 9 – Green outline), based on a maturity and formation characteristics map, stretching from the Magnus and Bruce fields in the north through the Brae/Sleipner fields in the South Viking Graben to the Norwegian Ekofisk "chalk" reservoirs which overly the Kimmeridge to the south in the Central Graben.

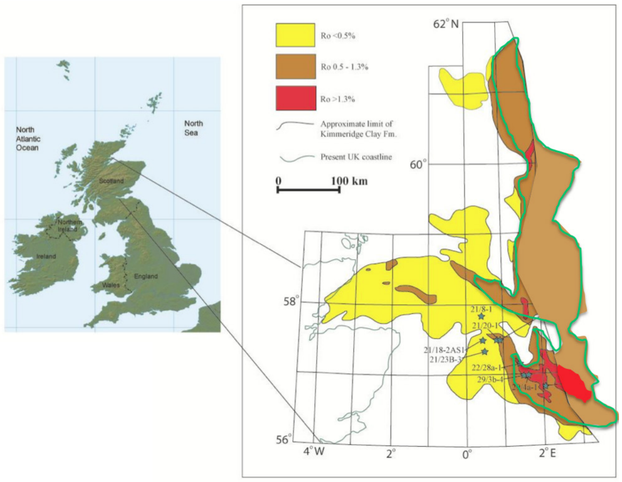

Figure 9: Present day Kimmeridge Clay Maturity Map (Orange = Peak Oil, Red = Oil/Gas, Yellow = Early Oil). Our Kimmeridge Clay "core area" is within the green

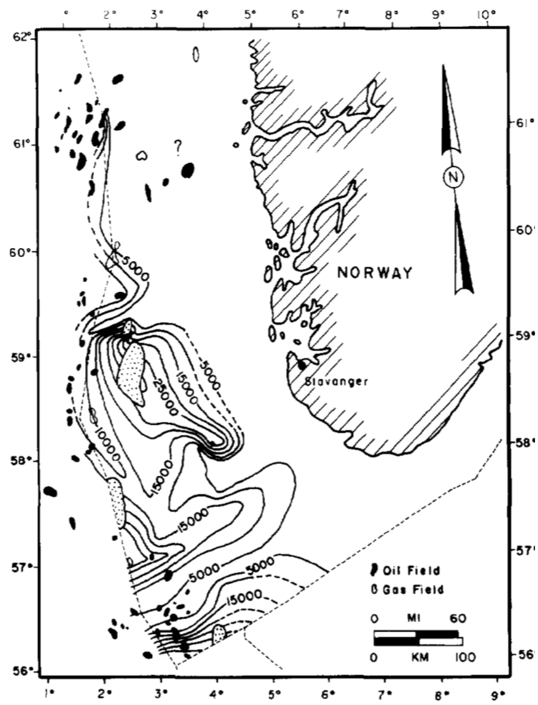

Figure 10: Original generative potential of the Kimmeridge Clay (ppm) in the Norwegian Sector of the North Sea. Highest capacities correspond to the Viking and Central Grabens and the Norwegian-Danish Basin (Report Baird, 1986, AAPG, Vol 70, 1)

Outlook for the North Sea...and Could Unconventional Exploration and Exploitation Play a Role

The North Sea, particularly the UK segment has seen production decline for some time since 2001 (Figure 11). Only 15 wells were drilled in 2013, with less than 100mbbls of oil discovered in the last two years, according to Oil & Gas UK, and despite 13 fields being brought on production. There is still life in the old basin but there is also a growing sense that time is running out, with exploration and appraisal drilling down 30% in the UK sector, with the Norwegian sector faring much better, possibly due to the better financial support for exploration drilling. There is a general feeling that future decent sized discoveries will be rare in the basin center, where the Kimmeridge Clay is currently mature for gas and/or oil. Additionally, many of the fields that are in the "core" of the Kimmeridge Clay play offshore, are facing abandonment within the next ten years (Figure 12). An example of a key field which is in the process of being abandoned that could test the Kimmeridge unconventional potential, is Miller in the South Viking Graben.

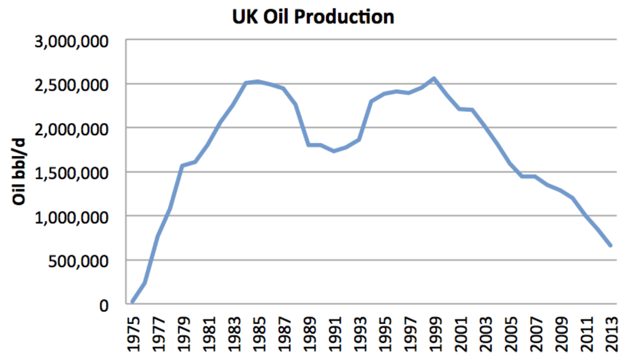

Figure 11: UK North Sea oil production, showing significant decline over the past 13 years

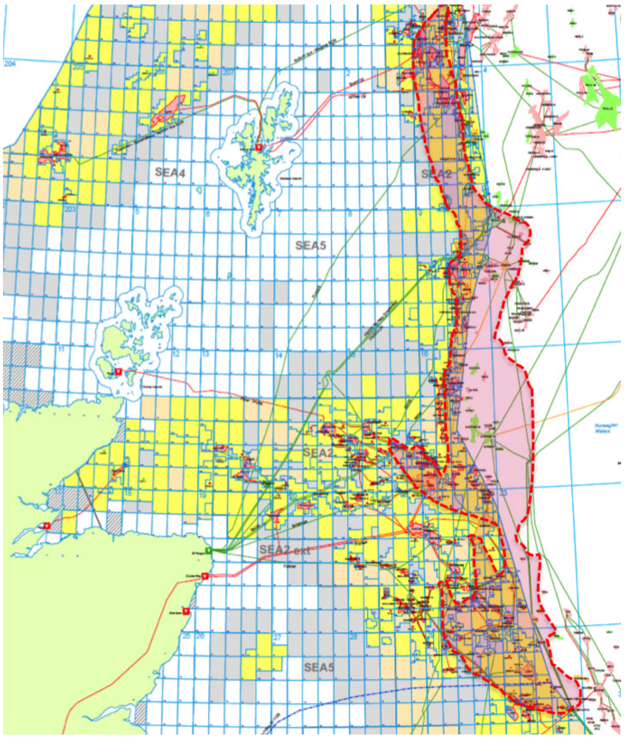

Figure 12: Infrastructure map of the North Sea showing fields and licences, and pipelines (Oil = Red, Gas = Green), and the "core" of the Kimmeridge Clay in dashed red

The Miller Field lies in blocks 16/7b and 16/8b in the Central North Sea and was discovered by BP and Conoco in 1982/1983. The Field is located 230km north-east of St Fergus in water depths of approximately 103m (338ft). Recoverable reserves from the Field were originally estimated to be in excess of 300Mbbl of oil and associated gas. Production started in 1992, however by 2007 the Field had declined and was producing less than 10,000bbl/d (Figure 13a).

The decision to decommission the field was approved in 2013 with an estimated overall cost to be in the order of £300 million. Operations are underway to start the removal of equipment, but it will be several years until this is completed, and pipelines and other shared infrastructure will remain in place.

With this example of Miller being the tip of the iceberg, and the cost of decommissioning being so high over the next 10 years, any opportunity to prolong field life is likely to have a positive investment result. Additionally, the political implications of keeping the North Sea going for a little longer are strong, given the need for revenue from the UK (and possibly future independent Scottish) governments.

Figure 13a

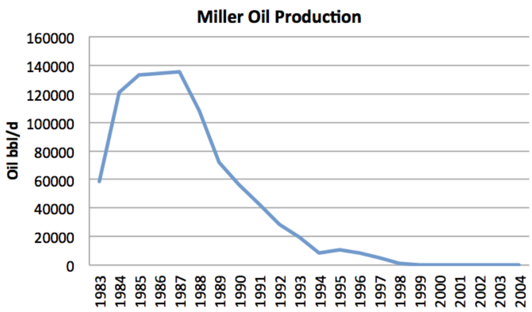

Figure 13b

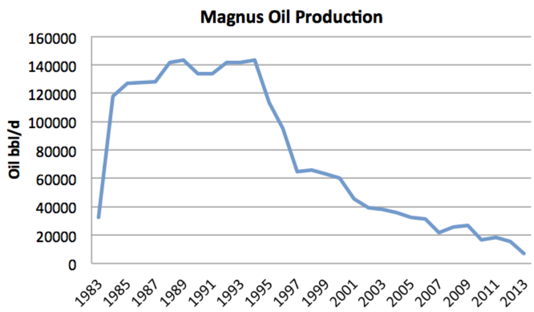

Figure 13: Oil production from Magnus and Miller feilds, both of which have reservoirs within or close to the Kimmeridge Clay formation

However, before all the infrastructure is dismantled there may still be a role for unconventional exploration over the next ten years. Based on the published maturity and generative characteristics of the Kimmeridge Clay in the centre of the basin, the "core" area contains 88 producing fields (62 in UK sector and 26 in the Norwegian sector). Of these fields, 31 have reservoirs close to the Kimmeridge Clay and could potentially see their wells used to target the play with unconventional completion techniques. Costs would be contained by either reentering old wells or using rigs on the production platforms, and these fields offer the highest potential for any future unconventional exploration in the North Sea. A potential candidate to test this concept over the next few years could be the Magnus field, which like Miller, has also seen its production decline to a fraction of its peak (Figure 13b).

Additionally, we estimate that the following fields (Figures 14 & 15) would be potential candidates to attempt unconventional production from the Kimmeridge Clay in the North Sea. This could be made more feasible if UK and Norwegian government tax incentives were put in place for such activities that would help prolong the life of the basin, and allow it to continue to generate revenue. However, some of these fields despite being in the "core" area of the play, may require significant additional investment which could lead to the exploration of the play being uneconomic in many cases.

Field	North Sea Basin	Producing reservoir	Kimmeridge Exploration Potential
Brage	NVG	Lower Jurassic/Triassic; Middle Jurassic; Late Jurassic	High
Gudrun	SVG	Upper Jurassic Draupne Formation	High
Gyda	CG	Upper Jurassic Ula	High
Tambar	CG	Upper Jurassic Ula	High
Troll	NVG	Late Jurassic Sognefjord formation and Middle Jurassic	High
Ula	CG	Upper Jurassic Ula	High
Varg	SVG	Upper Jurassic	High
Vigdis	NVG	Lower Jurassic/Triassic; Middle Jurassic; Late Jurassic	High
Gullfaks	NVG	Lower Jurassic/Triassic; Middle Jurassic	Medium
Hild	NVG	Middle Jurassic Brent Group	Medium
Huldra	NVG	Middle Jurassic Brent Group	Medium
Kvitebjorn	NVG	Lower Jurassic/Triassic; Middle Jurassic	Medium
Oseburg	NVG	Lower Jurassic/Triassic; Middle Jurassic	Medium
Sleipner	SVG	Middle Jurassic Sleipner Formation	Medium
Snorre	NVG	Lower Jurassic/Triassic (Statfjord Formation)	Medium
Stratfjord	NVG	Lower Jurassic/Triassic; Middle Jurassic	Medium
Tune	NVG	Middle Jurassic Brent Group	Medium
Veslefrikk	NVG	Lower Jurassic/Triassic; Middle Jurassic	Medium
Visund	NVG	Lower Jurassic/Triassic; Middle Jurassic	Medium
Balder	SVG	Latest Paleocene-earliest Eocene Balder Formation	Low
Ekofisk	CG	Cretaceous Chalf and Paleocene Tor formation	Low
Glitne	SVG	Paleocene Heimdal formation	Low
Grane	SVG	Paleocene Heimdal formation	Low
Heimdal	SVG	Paleocene Heimdal formation	Low
Jotun	SVG	Paleocene Heimdal formation	Low
Tor	NVG	Cretaceous Chalf and Paleocene Tor formation	Low

CG = Central Graben; SVG = S. Viking Graben; NVG = N. Viking Graben; WGG = Witch Ground Graben

Figure 14: Table showing fields in the Norwegian sector of the North Sea within the area of the highest Kimmeridge Clay (KC) potential. High potential = fields with wells and reservoirs close to or within the KC; Medium potential = fields with wells and reservoirs in the Jurassic below the KC; Low potential are field with stratigraphically shallower or deeper reservoirs to the Jurassic

KIMMERIDGE
Energy

Field	North Sea Basin	Producing reservoir	Kimmeridge Source Rock Potential
Alwyn	NVG	Lower Jurassic/Triassic; Middle Jurassic; Late Jurassic	High
Birch	SVG	Late Jurassic Brae Formation	High
Brae	SVG	Late Jurassic Brae Formation	High
Devenick	SVG	Late Jurassic Brae Formation	High
Drake	SVG	Upper Jurassic Ula Formaion	High
Dunbar	NVG	Lower Jurassic/Triassic; Middle Jurassic; Late Jurassic	High
Elgin	CG	Upper Jurassic Fulmar sandstone	High
Erskine	CG	Middle Jurassic; Late Jurassic	High
Glenelg	CG	Upper Jurassic Fulmar sandstone	High
Halley	CG	Upper Jurassic Fulmar sandstone	High
Hawkins	SVG	Upper Jurassic Fulmar sandstone	High
Kingfisher	SVG	Late Jurassic Brae Formation and Middle Jurassic Heathe	High
Larch	SVG	Late Jurassic Brae Formation	High
Magnus	NVG	Late Jurassic intra-Kimmeridge Clay Formation	High
Miller	SVG	Late Jurassic Brae Formation	High
Seymour	SVG	Upper Jurassic Fulmar sandstone	High
Shearwater	CG	Upper Jurassic Fulmar sandstone	High
Thelma	SVG	Late Jurassic Brae Formation	High
Tiffany	SVG	Late Jurassic Brae Formation	High
Toni	SVG	Late Jurassic Brae Formation	High
Piper	WGG	Late Jurassic intra-Kimmeridge Clay Formation	High
Claymore	WGG	Late Jurassic intra-Kimmeridge Clay Formation	High
Tartan	WGG	Late Jurassic intra-Kimmeridge Clay Formation	High
Beryl	SVG	Middle Jurassic Beryl Formation	Medium
Brent	NVG	Middle Jurassic; Lower Jurassic/Triassic	Medium
Bruce	SVG	Middle Jurassic Beryl Group	Medium
Crawford	SVG	Middle Jurassic; Lower Jurassic/Triassic	Medium
Deveron	NVG	Middle Jurassic Brent Group	Medium
Don	NVG	Middle Jurassic Brent Group	Medium
Dunlin	NVG	Middle Jurassic Brent Group	Medium
Jade	CG	Middle-Late Triassic Skaggerak Formation	Medium
Jasmine	CG	Middle-Late Triassic Skaggerak Formation	Medium
Judy	CG	Middle-Late Triassic Skaggerak Formation	Medium
Murchison	NVG	Middle Jurassic Brent Group	Medium
Nevis	SVG	Triassic and Middle Jurassic Beryl Formation	Medium
Ninian	NVG	Middle Jurassic Brent Group	Medium
Strathspey	NVG	Middle Jurassic Brent Group	Medium
Thistle	NVG	Middle Jurassic Brent Group	Medium
Affleck	CG	Cretaceous Chalk	Low
Andrew	SVG	Paleocene Andrew Formation	Low
Blane	CG	Palaeocene sandstone of the Forties Formation	Low
Buckland	SVG	Latest Paleocene-earliest Eocene Balder Formation	Low
Cyrus	SVG	Paleocene Andrew Formation	Low
Enoch	SVG	Palaeocene sandstone	Low
Farragon	SVG	Palaeocene sandstone	Low
Fleming	SVG	Palaeocene, Maureen Formation	Low
Gryphon	SVG	Latest Paleocene-earliest Eocene Balder Formation	Low
Harding	SVG	Eocene	Low
Harrier	CG	Paleocene Andrew Formation and U. Createous Chalk	Low
Joanne	CG	Cretaceous Chalk	Low
Kinnoull	SVG	Paleocene Andrew Formation	Low
Leadon	SVG	Eocene	Low
Lomond	CG	Latest Paleocene-earliest Eocene Sele Formation	Low
Machar	CG	Cretaceous Chalk	Low
Maclure	SVG	Latest Paleocene-earliest Eocene Balder Formation	Low
Merganser	CG	Latest Paleocene-earliest Eocene Sele Formation	Low
Mirren	CG	Latest Paleocene-earliest Eocene Sele Formation	Low
Mungo	CG	Latest Paleocene-earliest Eocene Sele Formation	Low
Nuggets	NVG	Eocene	Low
Pierce	CG	Latest Paleocene-earliest Eocene Sele Formation	Low
Scoter	CG	Latest Paleocene-earliest Eocene Sele Formation	Low
Stella	CG	Paleocene Andrew Formation	Low

CG = Central Graben; SVG = S. Viking Graben; NVG = N. Viking Graben; WGG = Witch Ground Graben

Figure 15: Table showing fields in the UK sector of the North Sea within the area of the highest Kimmeridge Clay (KC) potential. High potential = fields with wells and reservoirs in the Jurassic below the KC; Low potential are field with stratigraphically shallower or deeper reservoirs to the Jurassic

Summary

The Kimmeridge Clay has been largely overlooked as a source rock for unconventional activity due to the fact that its most prospective core location lies offshore in the North Sea. However, we would suggest that its hydrocarbon generative potential has been overlooked to date in the North Sea. By our calculations, if the Kimmeridge Clay in the North Sea was located onshore today the oil industry would be scrambling to explore and exploit around 50Bnboe of recoverable volumes (assuming a 5% recovery rate) from this potential unconventional play. However, it is not onshore and the only hope of exploring and recovering hydrocarbons from the "core" of the Kimmeridge Clay in the North Sea, is through re-entering wells from existing platforms before they are decommissioned. Is this so far-fetched an idea, given the decline in North Sea oil volumes and the potential financial benefit in delaying North Sea infrastructure abandonment (not to mention future incentives that might be given to the industry by the UK and Norwegian governments), to prolong the life of the basin through unconventional activity?

The Kimmeridge Clay is a world-class source rock with a long unconventional history and potentially a future role in taking unconventional activity offshore. Although it is not widely known today in the unconventional community, we hope that the name Kimmeridge will become a familiar one to many over the next decade.

KIMMERIDGE
Energy

Notice & Disclaimer

- This document and all of the information contained in it, including without limitation all text, data, graphs, charts (collectively, the "Information") is the property of Kimmeridge Energy Management Company, LLC or its affiliates (collectively, "Kimmeridge"), or Kimmeridge's licensors, direct or indirect suppliers or any third party involved in making or compiling any information (collectively, with Kimmeridge, the "Information Providers") and is provided for informational purposes only. The information may not be reproduced or redisseminated in whole or in part without prior written permission from Kimmeridge.
- The Information has been derived from sources believed to be reliable but is not guaranteed as to accuracy and does not purport to be a complete analysis of any security, company or industry involved. The user of the information assumes the entire risk of any use it may make or permit to be made of the information. NONE OF THE INFORMATION PROVIDERS MAKES ANY EXPRESS OR IMPLIED WARRANTIES OR REPRESENTATIONS WITH RESPECT TO THE INFORMATION (OR THE RESULTS TO BE OBTAINED BY THE USE THEREOF), AND TO THE MAXIMUM EXTENT PERMITTED BY APPLIABLE LAW, EACH INFORMATION PROVIDER EXPRESSLY DISCLAIMS ALL IMPLIED WARRANTIES (INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF ORIGINALITY, ACCURACY, TIMELINESS, NON-INFRINGEMENT, COMPLETENESS, MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE) WITH RESPECT TO ANY OF THE INFORMATION.
- Information containing any historical information, data or analysis should not be taken as an indication or guarantee of any future performance, analysis, forecast or prediction. Past performance does not guarantee future results. Opinions expressed are subject to change without notice.
- None of the Information constitutes an offer to sell (or a solicitation of any offer to buy), any security, financial product or other investment vehicle or any trading strategy.
- Kimmeridge Energy Management Company, LLC is a Registered Investment Adviser. Nothing herein is intended to constitute investment advice or a recommendation to make (or refrain from making) any kind of investment decision and may not be relied on as such.
- The Information has not been submitted to, nor received approval from, the United States Securities and Exchange Commission or any other regulatory body.

Contact Kimmeridge

New York
400 Madison Avenue,
Suite 14C, New York, NY 10017

London
Thornton House, Thornton Road
London, England SW19 4NG

Houston
952 Echo Lane, Suite 364
Houston, TX 77024

info@kimmeridgeenergy.com